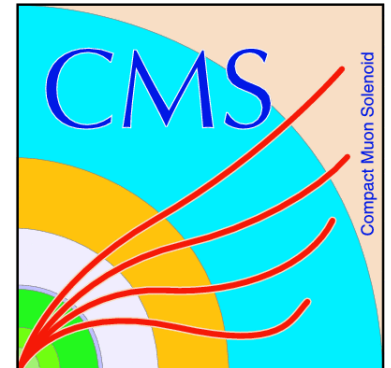


Measurement of $\Upsilon(nS)$ production at 7 TeV with the CMS experiment

Jacob Anderson
Fermilab

On behalf of the CMS collaboration

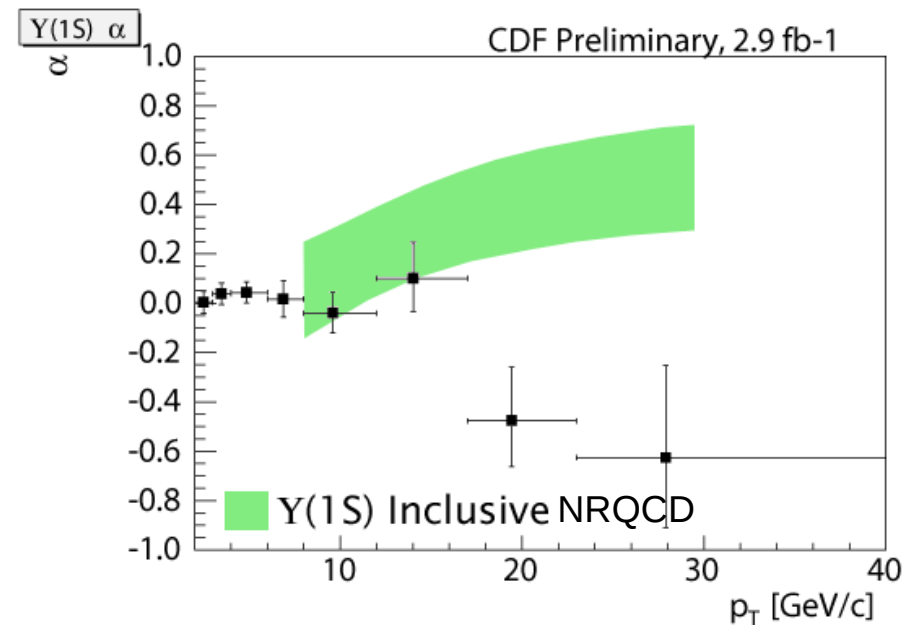


Outline

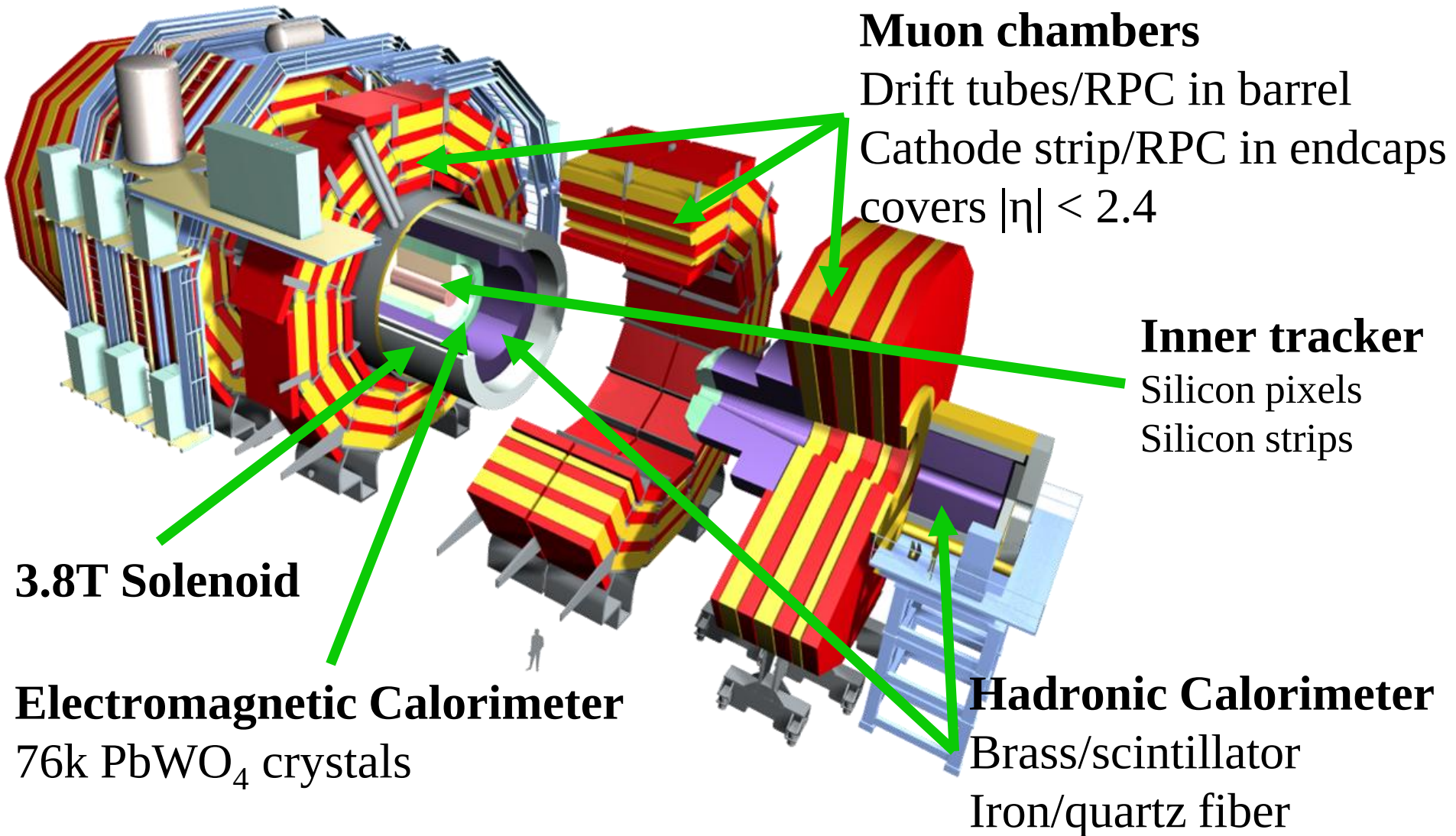
- Theoretical considerations
- The CMS detector
- The Υ cross-section
 - Signal selection
 - Analysis technique
 - Results and systematic uncertainties
- Comparisons with other experiments and theory
- Future considerations

Theory

- Quarkonia production at a hadron collider is not theoretically settled.
- Most models fail to simultaneously explain experimental measurements of both cross section and polarization.
- The LHC can provide new measurements to understand quarkonium production including a larger reach in p_T .

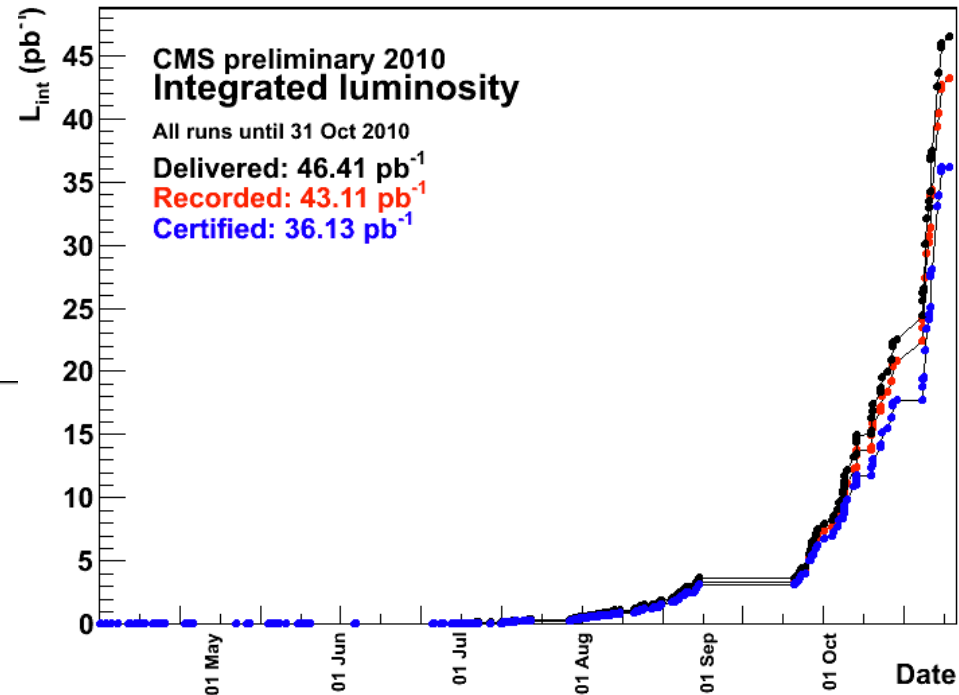
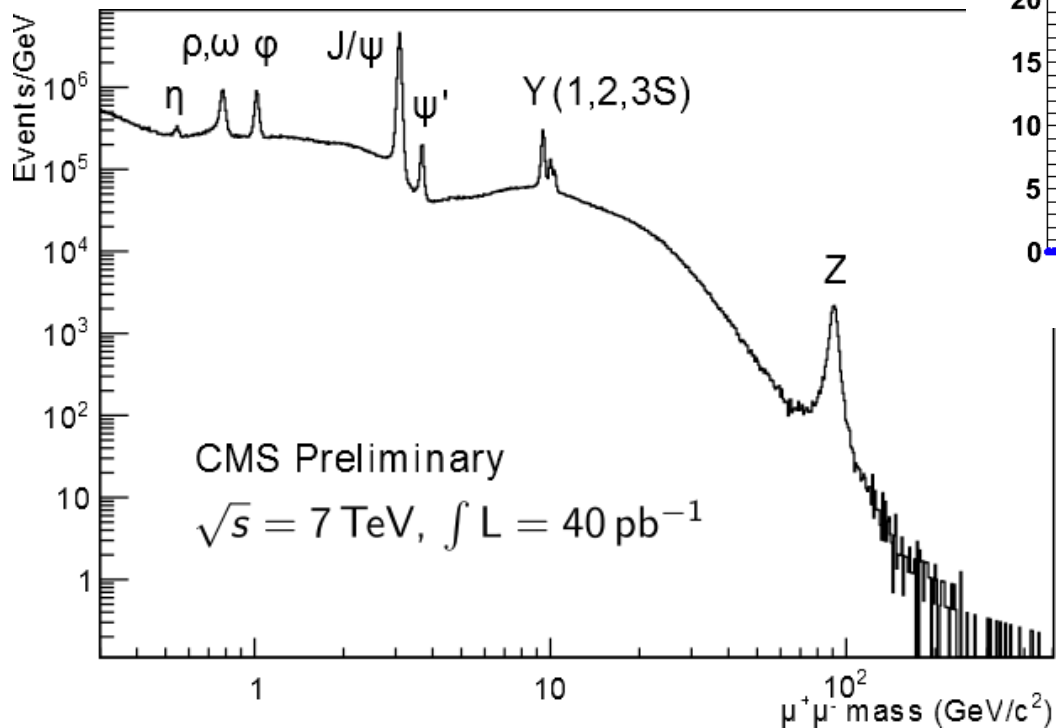


The CMS detector



The dataset

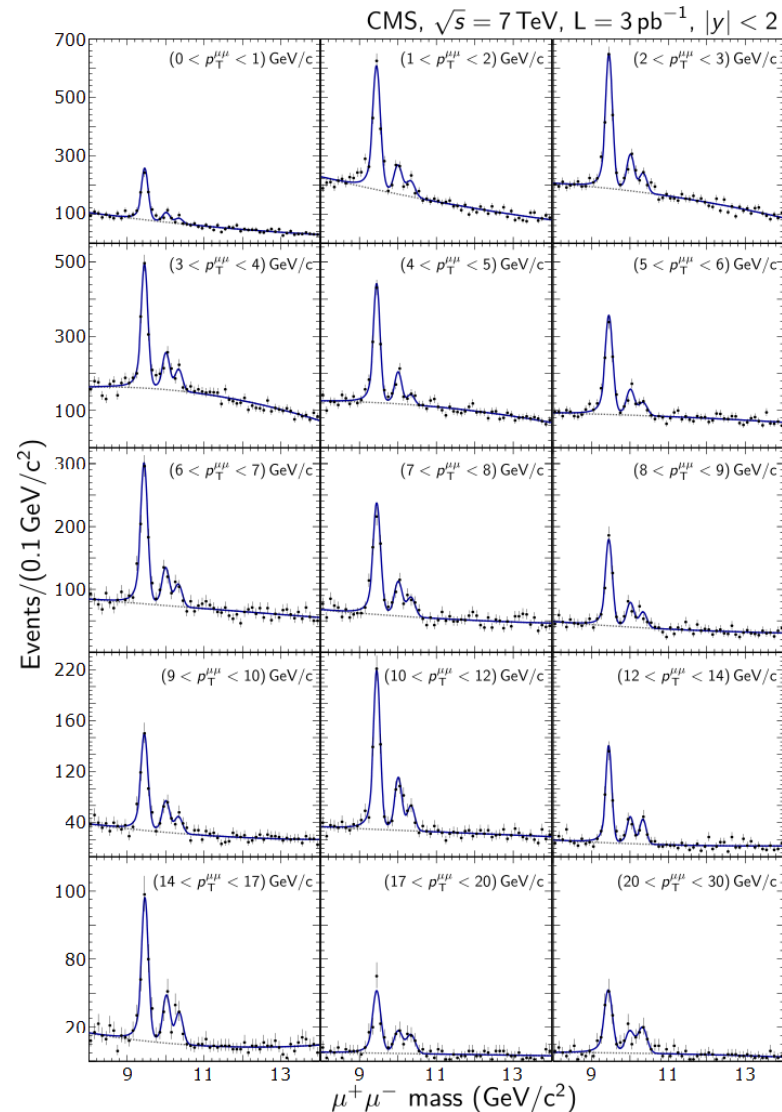
- Results here are using 3 pb^{-1} of data collected in 2010.
- Full 2010 data set is 40 pb^{-1} .



- Heavy ion data is also being analyzed.
- More data is being delivered now.

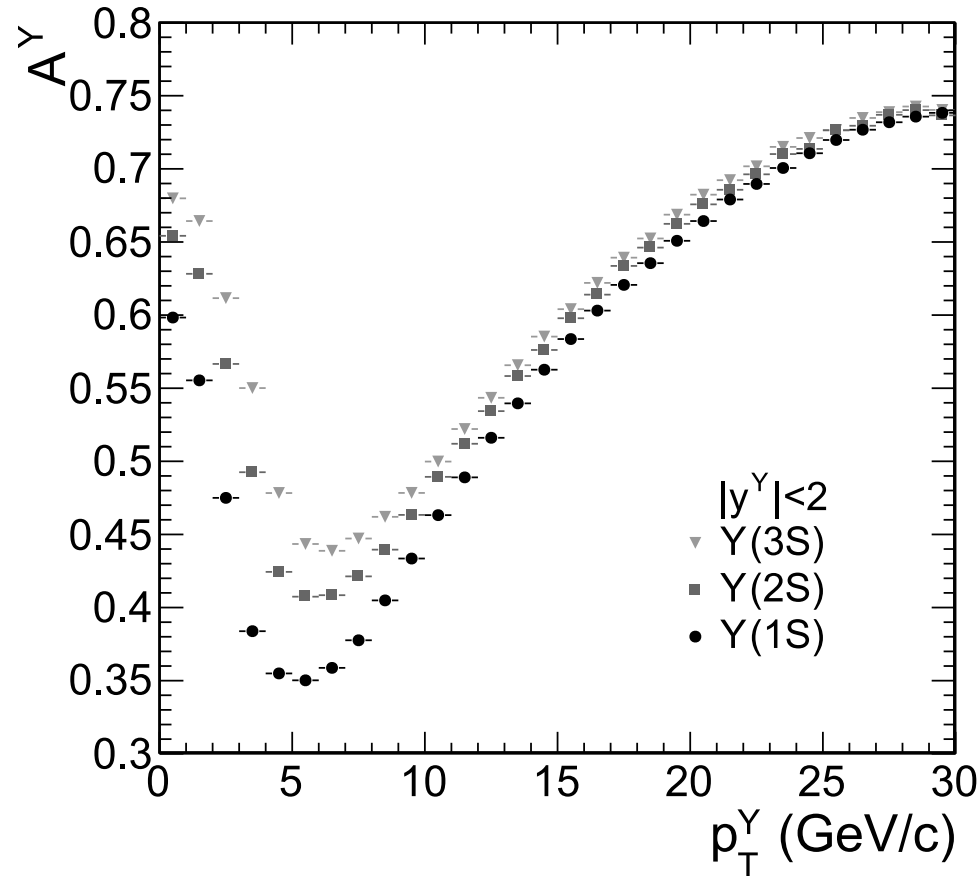
Υ candidate selection

- **muon selection**
 - Kinematic acceptance
 - $p_T > 3.5$ GeV/c if $|\eta| < 1.6$
 - $p_T > 2.5$ GeV/c if $1.6 < |\eta| < 2.4$
 - track $\chi^2/n_{\text{dof}} < 5$
 - $N_{\text{Si hits}} > 12$
 - tracking parameters and impact parameter consistent with primary vertex
 - muons matched to a dimuon trigger at Level 1
- **dimuon selection**
 - opposite sign muon pairs
 - vertex probability $> 0.1\%$
 - $|y| < 2.0$



Υ acceptance

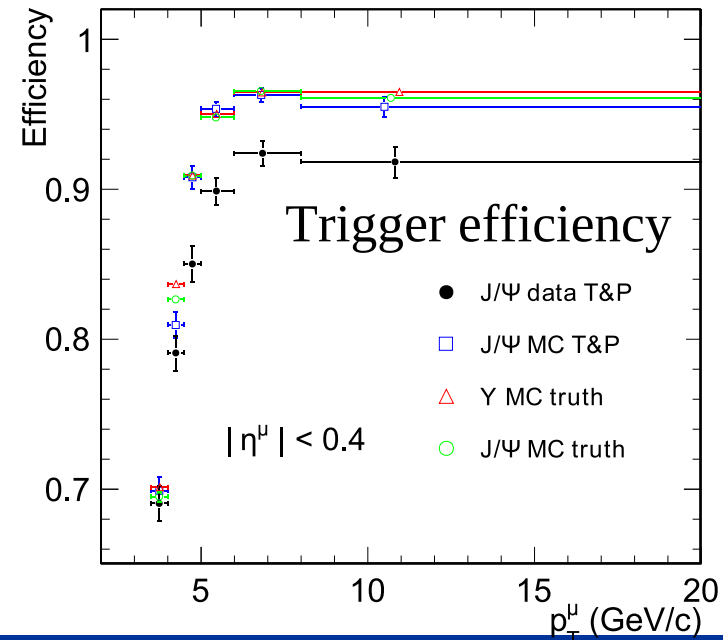
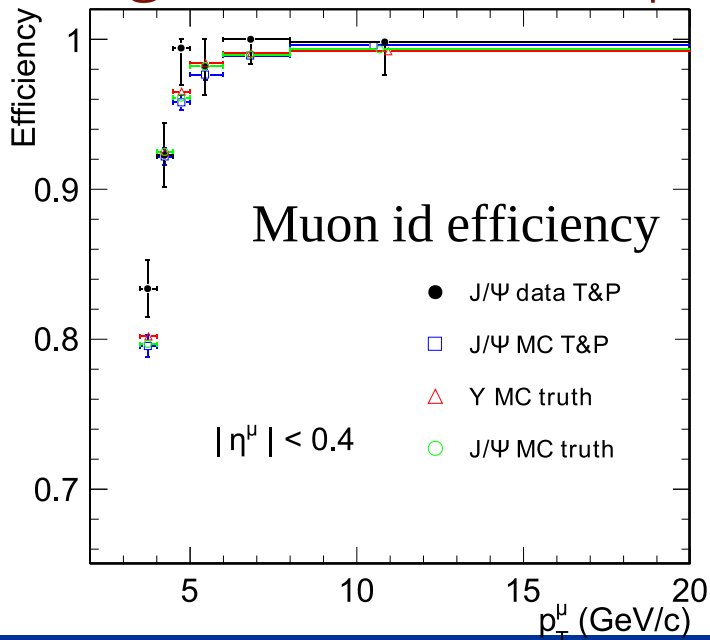
- Acceptance is evaluated using MC for its dependence on Υ p_T and y .
- In addition, the acceptance is strongly dependent on the unknown production polarization.
 - Acceptance changes by as much as 20%.
 - Results are quoted for unpolarized case and for longitudinally and transversely polarized in both the Collins-Soper and helicity frames.



Muon efficiency

- Efficiency is factorized.

$$\varepsilon(\text{total}) = \varepsilon(\text{trigger}|\text{muon}) \times \varepsilon(\text{muon}|\text{track}) \times \varepsilon(\text{track}|\text{accepted})$$
- Tracking efficiency is evaluated using a track-embedding technique to find an efficiency $\sim 98\%$ and flat in p_T and η .
- Muon identification and trigger efficiencies are evaluated data using data from the J/ψ resonance.



Results

- Integrated, unpolarized cross section $|y| < 2$

$$\sigma(\text{pp} \rightarrow \Upsilon(1\text{S})X) \cdot \mathcal{B}(\Upsilon(1\text{S}) \rightarrow \mu^+ \mu^-) = 7.37 \pm 0.13(\text{stat.})_{-0.42}^{+0.61}(\text{syst.}) \pm 0.81(\text{lumi.}) \text{ nb}$$

$$\sigma(\text{pp} \rightarrow \Upsilon(2\text{S})X) \cdot \mathcal{B}(\Upsilon(2\text{S}) \rightarrow \mu^+ \mu^-) = 1.90 \pm 0.09(\text{stat.})_{-0.14}^{+0.20}(\text{syst.}) \pm 0.24(\text{lumi.}) \text{ nb}$$

$$\sigma(\text{pp} \rightarrow \Upsilon(3\text{S})X) \cdot \mathcal{B}(\Upsilon(3\text{S}) \rightarrow \mu^+ \mu^-) = 1.02 \pm 0.07(\text{stat.})_{-0.08}^{+0.11}(\text{syst.}) \pm 0.11(\text{lumi.}) \text{ nb}$$

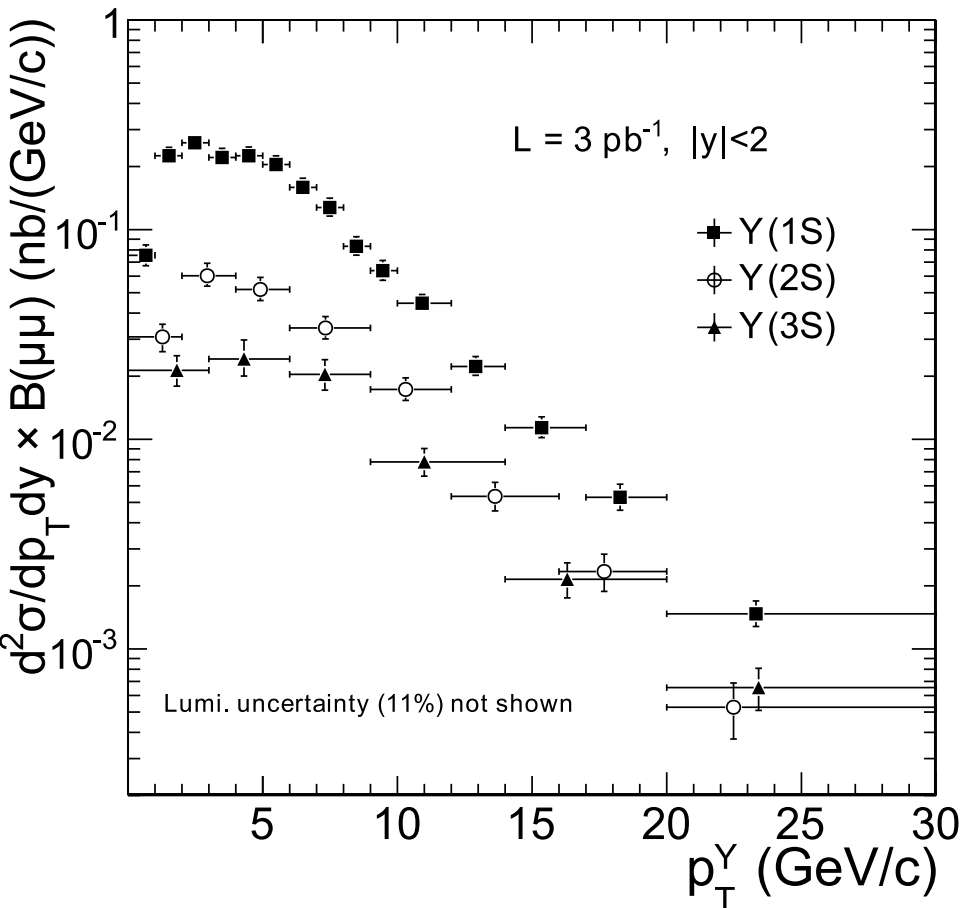
- Dominant systematic uncertainties

- Luminosity (11%)
- Muon identification and trigger efficiencies (8%)

- A different polarization can change the cross section by as much as 20%.

Results

$d\sigma/dp_T$ (unpolarized)

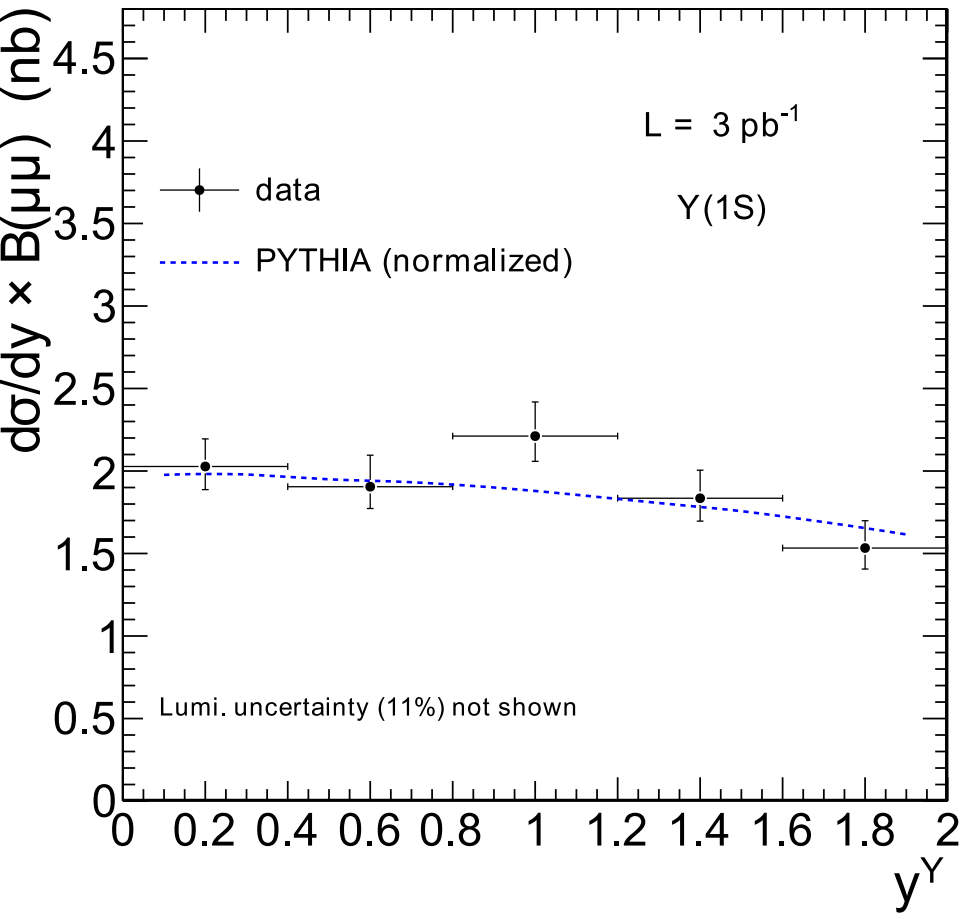


Variation due to polarization

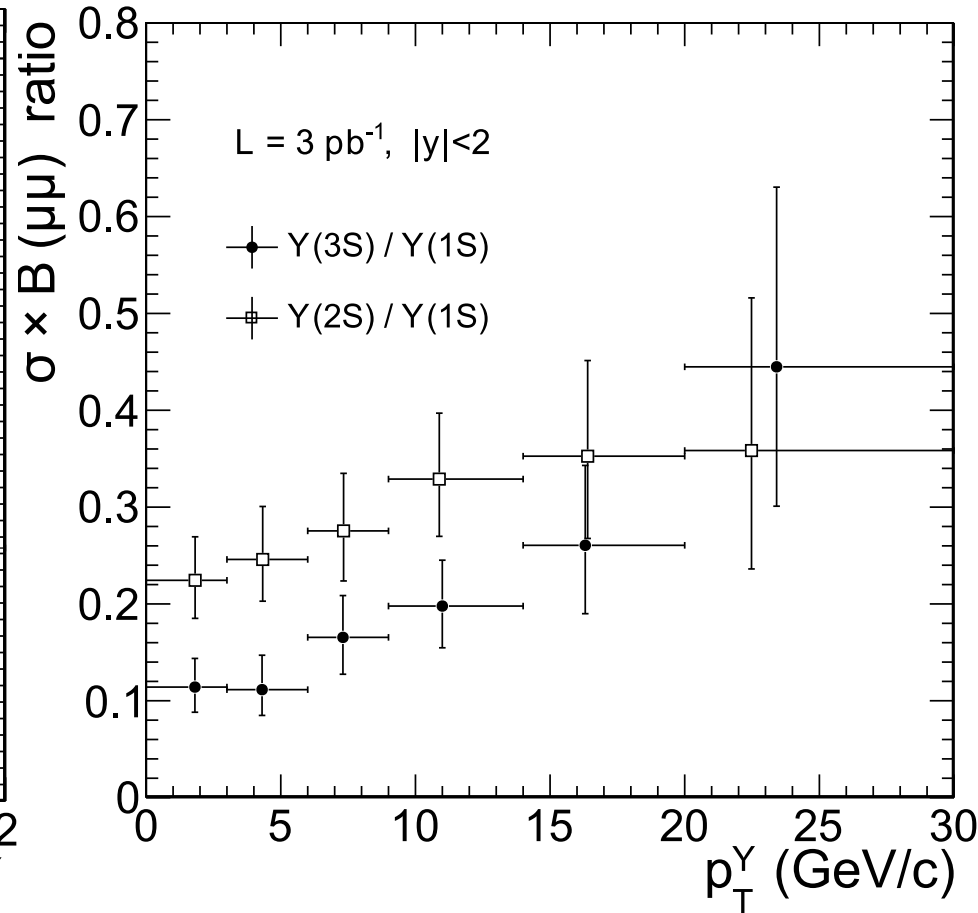
HX-T	HX-L	CS-T	CS-L
(%)	(%)	(%)	(%)
< 1			
+16	-22	+13	-16
+14	-19	+18	-24
+14	-20	+18	-23
+18	-23	+8	-12
+18	-23	-1	+2
+18	-23	-4	+10
+15	-20	-5	+12
< 1			
+14	-19	+12	-15
+10	-14	+17	-22
+13	-18	+14	-19
+17	-22	+1	-2
+17	-22	-4	+8
+14	-20	-5	+11
< 1			
+14	-19	+10	-13
+11	-16	+14	-19
+16	-22	+1	-1
+15	-21	-4	+10

Results

$d\sigma/dy$

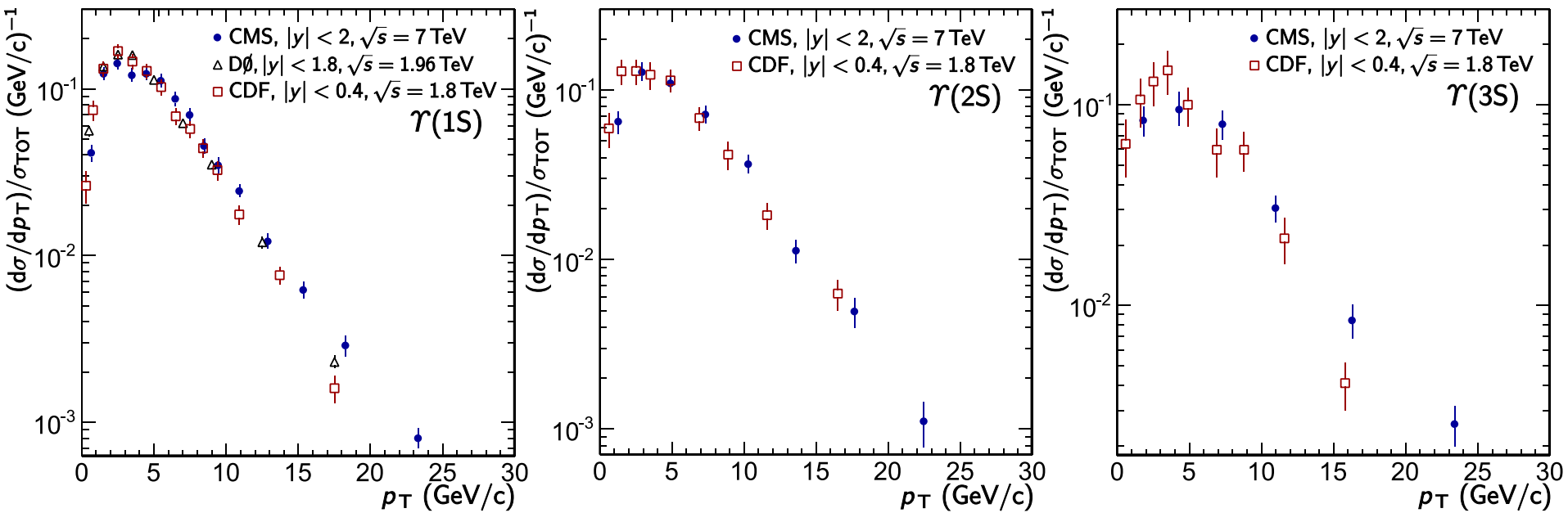


$\sigma(nS)/\sigma(1S)$



Comparison to Tevatron

- Good agreement



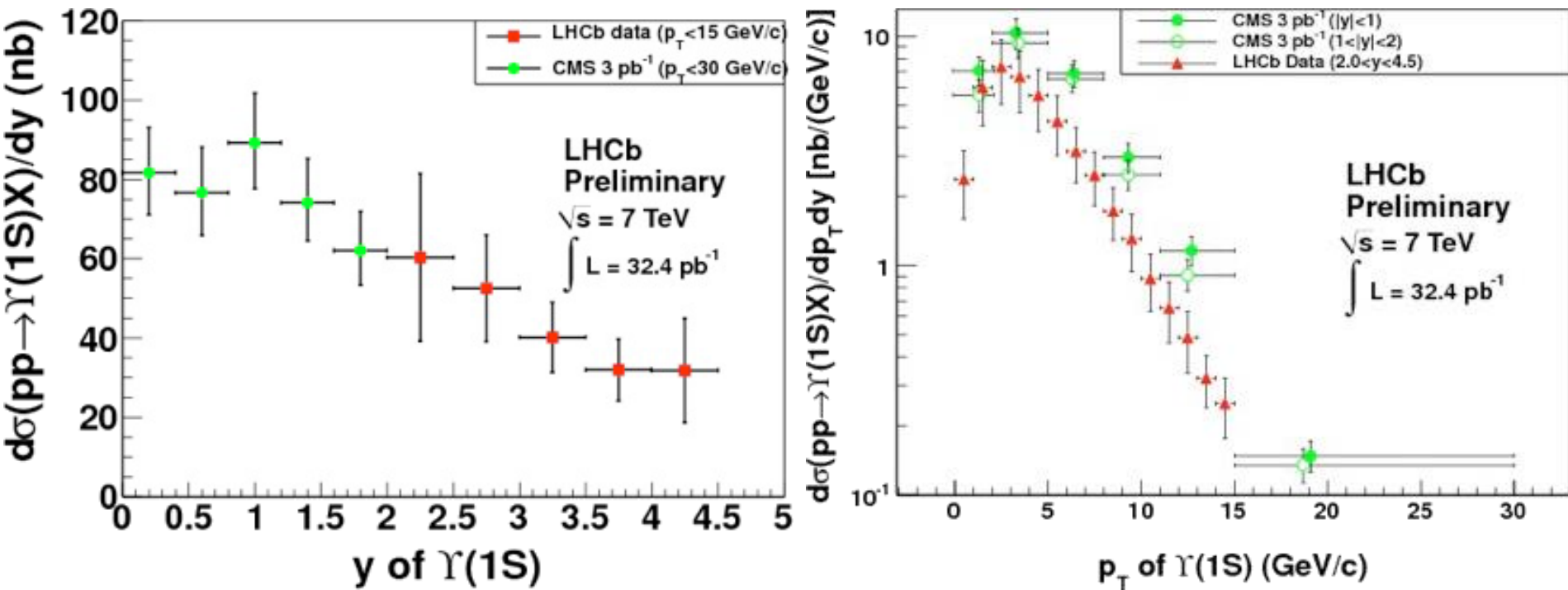
PRL **88** 161802 (2002)

PRL **100** 049902 (2008)



Comparison to LHCb

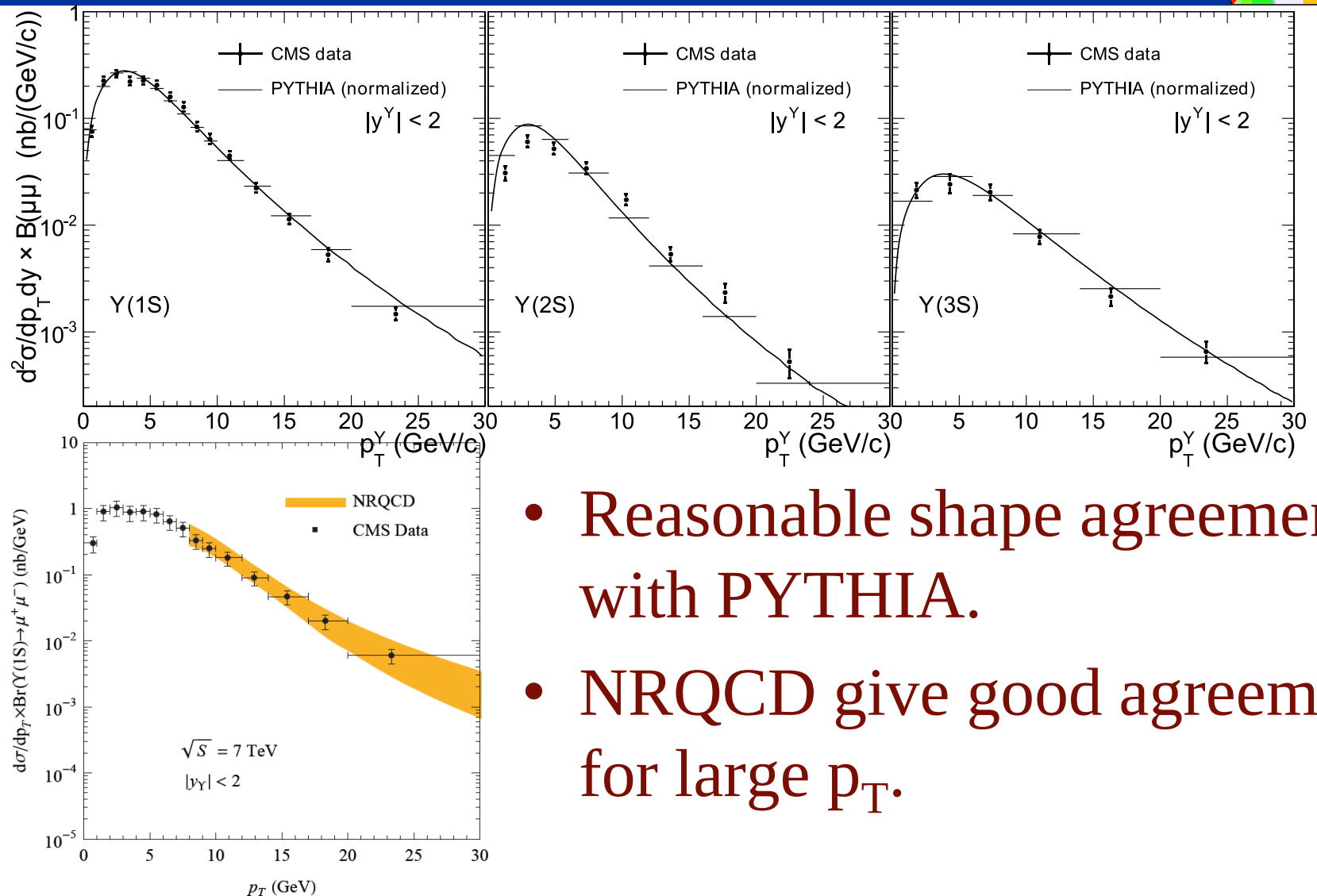
- Complimentary and consistent results



LHCb-CONF-2011-016



Comparison to theory



- Reasonable shape agreement with PYTHIA.
- NRQCD give good agreement for large p_T .

Summary and the future

- CMS was the first to measure the $\Upsilon(nS)$ cross section at the LHC and has found it to be compatible with expectations based on experience from the Tevatron and predictions from theory.
- The data sample has significantly increased, and for the future, CMS will update our cross section measurement as well as adding analyses to look at polarization and Υ production in heavy ion collisions.
- **More is yet to come!**



Stay tuned

